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EELGRASS DEPLETION ON THE PACIFIC COAST AND ITS EFFECT UPON BLACK BRANT

By James Moffitt, Curator, Department of Ornithology and Mammalogy, California Academy of Sciences, and Clarence Cottam, Biologist, Section of Food Habits, Division of Wildlife Research

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Eelgrass (*Zostera marina*), a marine pondweed, is normally an abundant plant of sheltered salt and brackish waters of both coasts of North America. It is an important cover plant of mud flats where it supports much invertebrate life and thus, indirectly, many kinds of fishes, shellfishes, and crustaceans that are economically important to man. It also has been harvested commercially for industrial use as packing and insulating material. Further, it forms an important winter food for a number of game waterfowl, notably for sea brant.

In 1931, along the Atlantic coast, a widespread and almost complete destruction of this plant occurred within a few months' time, causing a serious shortage in the food supply for brant. Since it was feared that the disease or conditions responsible might spread to the Pacific coast, eelgrass there was watched for indications of decline. The first evidence of this was suspected in Tomales Bay, Calif., in the winter of 1937-38, but the depletion was so slight that it was considered of little significance. Apparently gradual diminution of eelgrass continued from about that time in several California bays, but in contrast to the Atlantic-coast catastrophe the decline in the Pacific was so gradual as to be scarcely noticeable up to 1940. By fall of that year, however, it was clear that substantial losses had occurred. This was plainly evidenced not only by areas of greatly reduced growth of eelgrass, but also by marked changes from the normal feeding habits of the brant.

DISTRIBUTION OF EELGRASS

Eelgrass is a perennial herb of the pondweed family with long, bright-green, ribbonlike leaves. Although it grows submerged, sometimes exposed by low tides, it occurs in water, up to 10 or more feet deep at low tide, that varies in salinity from full to half the concentration of sea water. Sometimes found along open coasts, it favors sheltered places, estuaries, and river mouths, where normal stands may form dense masses so luxuriant as to make boating difficult. The leaves trail upward in the water, often reaching the surface, where they form "slicks". Waterfowl feed on the seeds, underground root stalks, and leaves, which are sometimes grazed by the birds to uniform levels.

Eelgrass reproduces by seeds and by division of its underground stems, called rhizomes. Reproduction and growth, according to Setchell (1929)[1] are closely dependent upon water temperatures ranging between 50 and 68 degrees Fahrenheit, and quiescence occurs beyond these limits.

The species Z. marina has a wide distribution along the shores of the Atlantic and Pacific oceans. Along the coast of Europe it occurs from Norway to the Mediterranean, and in the west Atlantic from Greenland to southern North Carolina. In the Pacific, it extends from Bering Sea south to Magdalena Bay, Baja California (specimens in the California Academy of Sciences), and along the Asiatic coast at least to southern Japan. Related species occur in the southern hemisphere, including Australia.

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[1] Publications referred to parenthetically by date are listed in the Bibliography, p. 19.

Considerable variation exists in Z. marina over much of its range, which has led to the naming of a number of varieties. The typical plant, var. typica, which is rather short and narrow-leaved, is supposed to inhabit both coasts of the Atlantic Ocean, but Lynch and Cottam (1937) have shown that there is much local variation in size. Plants with leaves 6 feet long and $\frac{1}{2}$ inch wide are found in Maine, and there is an irregular but progressive reduction in size, southward, until in North Carolina the leaves are often only 5 or 6 inches long and proportionately narrower.

These investigators found that preserved specimens of eelgrass from the Atlantic Coast grouped nicely on the basis of size into fairly distinct regional varieties, and that each region represented definite ecological conditions. A similar situation appears to exist on the Pacific Coast of North America. Here botanists have generally regarded the robust form of eelgrass which occurs from Puget Sound to San Diego as var. latifolia. Large specimens may have leaves 8 to 10 feet in length and more than $\frac{1}{2}$ inch wide. Much smaller plants, however, occur both north and south of this area. Specimens from Magdalena Bay have leaves only 5 to 6 inches in length and average 3/16 inch in width. They are about the width of, but considerably shorter than, those of specimens from northern Europe which must be regarded as var. typica. Small-leaved samples have been recorded also from the Queen Charlotte Islands, British Columbia, and from Petersburg, Alaska. The botanical literature for Alaska and the Aleutian Islands generally records the plants of this area as referable to var. typica, indicating that they are of small size.

It seems, therefore, that ecological differences also obtain along the Pacific coast, rather than that var. typica occurs north and south of var. latifolia. Ecological conditions are probably at the optimum for the species where the robust latifolia type occurs. To the north and south, where conditions are not so favorable, possibly because of difference in temperature, the plant attains much smaller size.

Eelgrass on the Pacific coast is not likely to be confused with other marine plants. It may be well in this connection, however, to mention the closely related rock grass (Phyllospadix), the leaves of which are also up to 2 or 3 feet in length, although much narrower and somewhat thicker. Thus, they resemble a flattened string rather than a ribbon and are tougher than eelgrass leaves. Rock grass, which grows chiefly along rocky ocean shores from mean low water level to a depth of 12 feet, is well known to shellfishermen, as abalones are often found beneath its protecting cover. It is to some extent a food of brant in normal times but is taken in larger quantities during periods of eelgrass shortage.

EELGRASS DESTRUCTION ON THE ATLANTIC COAST

Lewis (1932), Cottam (1933b, 1933c, 1933d, 1934a, 1934c, 1935a, 1935c, 1935d, 1935f, 1938, 1941), Lewis and Cottam (1936), Lynch and Cottam (1937), Renn (1937), and others have summarized knowledge relating to the devastation of eelgrass that occurred along the Atlantic coast of North America from 1931 to 1941. Lami (1932), Lynn (1936), Cotton (1934), Butcher (1933), Lönnberg (in letters), and others have reported on the eelgrass situation in European waters. The greatest destruction was wrought in a few months' time in the summer and fall of 1931, when it was estimated that more than 90 percent of the Atlantic coast eelgrass was destroyed. In many places the destruction was nearly or entirely complete, and along most of the Atlantic coast of the United States fully 99 percent of the normal stand of the plant was destroyed within a year. The devastation was nearly as complete farther north along the Canadian coast, and almost simultaneously with the destruction of eelgrass in North America similar catastrophes occurred in the east Atlantic along the coasts of England, France, and Scandinavia. The rapidity of this destruction has no counterpart in botanical history. Periods of scarcity have previously occurred in in the Atlantic Ocean, both in American and European waters, but as reported by Cottam (1934, 1935e) none has approached the recent catastrophe in severity or extent.

Eelgrass has been slow to recover from the 1931 devastation, although improvement has repeatedly been noted. Most of this recovery, however, proved to be local and temporary until 1937. By 1938 numerous restricted growths of the plant were reported, but most were short-lived. These repeated temporary and sporadic recoveries seemed to be characteristic of the disease. Definite improvement over a large area was a pparent by 1940 (Cottam, 1941), although reestablishment was not uniform throughout the pla nt's range. Some localities in 1940 held almost normal stands of eelgrass, others showed an estimated recovery from 10 to 50 percent of normal, while some areas still remained in which little or no evidence of recovery was noted. Reestablishment over the entire Atlantic coast of the United States was at that time estimated as perhaps 10 to 20 percent of the 1930 crop. In general, areas of reduced salinity showed the greatest recovery. Recent reports showed most encouraging continued improvement.

A satisfactory explanation of the cause of the destruction of Atlantic coast eelgrass has not been given--indeed, it may never be adequately explained. Changes in temperature, salinity, or some unknown alteration of one or more of the physiochemical factors involved in the relationship between eelgrass and the surrounding water with its solutes have been suggested as possible explanations for the disease (Lewis 1932, Cottam 1933b, Young 1938a). Some workers have tried to correlate the periods of eelgrass scarcity with the occurrence of sunspots, or with the periodic shifting of the moon's

position in relation to the earth. These influences have been suggested as possibly responsible for the changed sea currents and environment (Stevens 1936b). The fact that eelgrass has survived more consistently at river mouths, and in other areas of reduced salinity, suggests that some change in the water has been a basic factor permitting or causing the wasting disease. Some pathologists maintain that the mycetozoan Labyrinthula, a low form of fungus, which was discovered in the tissues of diseased plants by C. E. Renn, is the causative organism (Renn 1936, Young 1938b). Its presence, shown by a blackening or streaking of the underground stems and a spotting, streaking, or blotching of the leaves, was detected in most of the diseased plants that were examined from the Atlantic coast. Peterson (1934b), and Mounce and Diehl (1934b), described another fungous disease, which they claimed was the cause of the eelgrass blight. On the other hand, Young (1938b) and Cottam (1939) reported that Labyrinthula had been found present on apparently healthy eelgrass in Departure Bay, British Columbia. Fischer-Piette, Heim, and Lami (1932), Heim and Lami (1933), and Lami (1933) reported that a bacterial disease was responsible for the malady, but this has not been confirmed. Other suggested causative factors for the disappearance are storms, changing nature of substratum or water levels, drought, oil, and pollution. Tutin (1938) believed that a deficiency of sunshine at the time of the great depletion in the British Isles in 1931-32 might have been a responsible factor, but Atkins (1938) challenged the theory, and Stevens (1939) showed that records for North America did not support the contention. Setchell (1922) has shown that Z. marina is rather sensitive to fluctuations in water temperature, and more recently (in a letter dated April 22, 1941) he suggests that such fluctuations may be a cause of depletion. Information at hand, however, does not seem to support this conclusion.

Whatever may be the cause of Atlantic-coast eelgrass destruction, it must be regarded as one of the most interesting and amazing biological phenomena of recent times.

EFFECT ON WATERFOWL

The effects of the blight were serious and far reaching among many forms of animal life that are either directly or indirectly dependent upon the plant. Among the direct dependents, the Atlantic brant (Branta bernicla hrota) suffered most. In normal times the diet of this species consists of about 80 percent Zostera. The winters of 1927-30 seem to have marked a period of peak abundance of sea brant along the Atlantic coast. After the disappearance of eelgrass in 1931, there was a precipitous and alarming reduction in the numbers of brant, and in 1934 it was estimated that perhaps not more than 20 percent of the normal population had survived. This resulted, in 1933, in a closed season, which, with the exception of the year 1935, is still in effect. As the depletion of eelgrass became acute,

brant became more and more emaciated and were found eating many kinds of unaccustomed food apparently having low nutritive value. In their efforts to obtain substitutes for Zostera, they were observed frequenting new and dangerous feeding places. During the shortage, brant were many times found feeding in pastures and green fields far from their normal habitat. Other bird species less directly dependent upon eelgrass than are brant, suffered considerably, though to a lesser degree, among these being Canada geese and black ducks. Scaup, redheads, and other kinds of coastal waterfowl also were involved.

Certain coastal fishes, especially perch and herring (Moffitt 1933: 255 and 1939: 338), many mollusks, crustaceans, and other small invertebrate life dependent upon Zostera, suffered severe depletion because of the eelgrass destruction.

The extent of the loss to mankind is difficult to estimate, but in the aggregate it is certainly large. Eelgrass, prior to its decline along the Atlantic coast, was harvested extensively for use as packing and insulating material, stuffing, upholstering, and as a compost for fertilizer. It also served as an effective breakwater and erosion preventive.

EELGRASS SITUATION ON THE PACIFIC COAST

The rapidity with which the eelgrass disease spread along the Atlantic coast, and perhaps even crossed that ocean within a few months' time in 1931, suggested that it might soon appear in the Pacific. Planting Atlantic coast oysters in California bays where eelgrass thrives has already caused the introduction of several undesirable invertebrates, including the oyster drill. This practice and that of ships carrying water ballast from the Atlantic and discharging it along the Pacific coast appeared likely means of introducing the eelgrass disease. Accordingly, interested persons were forewarned of the danger and were alert for its appearance.

In 1931, Moffitt (1931) commenced taking annual censuses of the black brant (B. b. nigricans) in California. The wintering bays favored by this species supported large growths of eelgrass, which normally forms at least 80 percent of the birds' diet. Since 1931, the censuses have been taken annually in cooperation with the California State Division of Fish and Game, and they probably will be continued for some time to come. During the past 10 years (Moffitt 1931-40) reports of these censuses have been published in the October issues of California Fish and Game (the quarterly journal of the California State Division of Fish and Game).

Because of the dependence of brant on eelgrass, and the danger of introduction of the disease, the condition of health of the plant was closely watched during the census work and on other visits to the coast. The first suggestion of decline was noted in the winter of 1937-38, when reports of certain departures from the normal feeding habits of the brant on Humboldt, Tomales, and Morro Bays, Calif., were thought to reflect eelgrass disease or depletion. During that winter Moffitt made no observations, but he reported those of others (1938: 345). With Cottam, on July 21, 1938, he inspected the eelgrass in Tomales Bay, when luxuriant and apparently healthy growths were found (Moffitt 1938: 34; Cottam 1939: 257). Close inspection of the plants at that time failed to show the leaf spotting and streaking, which are so characteristic of the disease. The winter of 1937-38 in California was one of abnormally high precipitation. Several prolonged periods of heavy rainfall resulted in high run-off with consequent lowering of the saline content of bay waters and much erosion, with the influx of much silt and foreign matter. Decreased salinity and silting due to excessive rainfall have been considered by some investigators as contributing factors to eelgrass depletion. Nevertheless, the eelgrass that was examined in July 1938 was clean, bright green in color and bore little silt.

During the 1938-39 season there were no noteworthy changes in eelgrass abundance in California, although in retrospect it now appears that a decline so gradual as to be scarcely noticeable was at that time taking place in several bays. The only abnormal behavior of brant observed in 1939 was the residence of 75 to 150 of the birds at Carmel Bay, Monterey County, during March and April. This is usually not a wintering area for the birds, and they were feeding principally upon rock grass. Their unusual presence and abnormal diet may have resulted from food shortage elsewhere.

The 1939-40 studies of brant and the 1940 California census (Moffitt 1940) showed a continuation of the decline of eelgrass in Tomales Bay, which was reflected by the abnormal behavior of early arriving birds and probably by the lower than average census for the area. A subnormal count obtained at Bodega Bay similarly may have been caused by eelgrass depletion.

By the winter of 1940, severe depletion of eelgrass was apparent in Tomales Bay, and by November 11, Moffitt estimated that there was perhaps not more than 25 percent as much eelgrass present on the extensive flats off Hamlet as there was in 1938. Later investigations through the winter and spring over the northern third of the bay in which most of the eelgrass formerly grew, resulted in the conclusion that only from 25 to 40 percent of a normal crop was present..

Because of the importance of eelgrass to oysters (Nelson 1923, 1924) and fishes (Moffitt 1933, 1939), this condition was promptly pointed out to the California State Division of Fish and Game. Paul Bonnot, fisheries expert of the Division, investigated and reported that, although material reduction of eelgrass had occurred in the past few years, there was no indication that the contributing cause was the disease of the Atlantic coast. What eelgrass he found seemed healthy. He advanced the explanation that the recent increased precipitation had resulted in a deposit of silt over the eelgrass beds, and that this might have been the cause.

Specimens of these plants, which were sent to Washington, were reported to bear at least some superficial evidences of disease, although the spotting was not nearly so great as in most diseased plants from the Atlantic coast. Samples also were sent to Renn, at Harvard University, for examination for Labyrinthula. He reported that these as well as other samples of eelgrass from Humboldt and other California bays showed some evidence of the disease, but did not entirely agree with diseased Atlantic coast plants. Renn's report states: "As near as I can make out, the leaf tissue has been invaded by Labyrinthula. The cell bodies and netlike pseudopodia appear in the green tissue in advance of the blackening just as in the Atlantic disease. The morphology of the Labyrinthula, however, is decidedly different in these fixed preparations. The cell bodies are uniformly spherical, the nuclear membrane is clearly defined, and there is a centrally located nucleolus. In none of the preparations could I find the spindle-shaped cell bodies characteristic of the Atlantic Labyrinthula. Of course, the spheres may represent a stage that I have not encountered before, or they may possibly indicate a difference in fixing or in other steps of preparation." After studying additional material from Mission Bay, Renn wrote that a species of Labyrinthula was definitely present, although from this limited information he could not estimate its role in the disappearance of the Pacific coast eelgrass. He recommended that leaf fragments be preserved in the following fluid, which can readily be prepared by any druggist: Formaldehyde (40-percent stock), 5 percent; acetic acid (glacial), 5 percent; 95-percent ethyl alcohol, 50 percent; copper sulphate (crystals), 1 percent, dissolved in distilled water, 99 percent. The eelgrass should be placed in this fixative immediately after it is taken from the water. The preservative solution should be used in quantities equivalent to 10 times the volume of the tissues to be fixed.

Moffitt and United States Game Management Agent Worcester inspected Tomales Bay on May 7, 1941, and noted abnormal brant behavior. They examined the eelgrass in several parts of the bay and found practically none growing in shallows 6 inches above mean low water. Formerly, considerable quantities had flourished above this level. The best growths observed on May 7 were on bottoms 18 or more inches below mean low water. The old leaves of these plants were relatively short, being from 3 to 4 feet in length, and they were uniformly covered with a slimy, gray, silty deposit. Their consequent gray color appeared abnormal and in marked contrast to the bright green color of the new growth, of which considerable was springing from the rhizomes; at that time these new leaves had attained a length of 8 to 10 inches. Possibly the slimy condition of the old leaves may have bee n a result of disease which presented a surface upon which silt would adhere more readily than it would upon healthy plants.

It appeared that the brant did not like to eat the silt-encrusted eelgrass, although at the time considerable quantities trailed upward within easy reach. Few of the birds present were found on the beds where they would normally have bee n, most of them feeding elsewhere on unaccustomed food (See p. 17).

These observations show that the organism suspected of having some relationship to the Atlantic coast eelgrass catastrophe is present in the denuded areas of the Pacific coast. Instead of the rapid disappearance that took place in the Atlantic, the eelgrass decline in the Pacific seems to have been gradual and much less severe.

PRESENT CONDITION OF EELGRASS ON THE PACIFIC COAST

In the course of this investigation correspondence with many persons was carried on concerning the present condition of Pacific eelgrass from Alaska te Baja California, and the number of replies was an indication of the wide interest in the subject. Acknowledgment of this cooperation is hereby made. The results of these investigations are briefly summarized, as follows:

Alaska

The eelgrass of Alaska is of small size. Since brant do not winter in consequential numbers even as far north as southeastern Alaska, the importance of this plant to the birds is principally as a food during migration.

Baronof and Chichagof Islands.--Through H. J. Hodgins, of Sitka, a report by Douglas Swanson, of the Fish and Wildlife Service, was provided for this area up to early in May 1941. At that time eelgrass was normally plentiful there, and a normal spring growth was appearing. No evidence of disease was found on plants examined, and none has been observed during the past year. Swanson reported that few brant occur on these islands except for a short period in spring during the northward migration. He judged the present supply of the plant to be sufficient for all waterfowl of the region.

Petersburg and Unalaska.--Ralph H. Imler, of the Fish and Wildlife Service, provided samples of the small-leaved eelgrass of the vicinity, which appeared to be healthy. On June 2, 1941, he reported having seen a number of brant feeding on kelp beds, and he observed others singly along Kuiu Island. On July 15, 1941, Frank Dufresne, of the Alaska Game Commission, wrote that further reports from Imler in southeastern Alaska, and Frank Beals on Umnak Island and Unalaska showed that the plants were normally abundant and healthy. On September 1, Imler further reported that eelgrass was in a healthy condition in southeastern Alaska.

On September 22 Frank Dufresne transmitted a package of 19 pressed specimens of eelgrass taken by Frank L. Beals, Labor Patrolman, at 12 localities along the Alaska Peninsula and Aleutian chain of islands. Most of the specimens were fruiting, and all appeared normal and healthy.

British Columbia

Through the cooperation of several Canadians considerable information has been obtained from this Province. Apparently the eelgrass is still healthy and abundant this far south in the Pacific. Some brant winter as far north as the central part of the coast of British Columbia, and in the vicinity of Vancouver Island and the opposite mainland they are common winter residents. Accordingly, the abundance of eelgrass is of greater importance to the species from central British Columbia southward.

Queen Charlotte Islands.--R. M. Stewart, of Masset, has provided valuable information and samples of the plants from the vicinity of Masset Inlet. He reported that eelgrass is not plentiful and can be found in only a few bays. The specimens sent in were extremely interesting, because two strains of the plant seemed to be represented. One, of fair size, had leaves up to 3 feet long and averaging 3/16 inch in breadth. Other samples were of extremely small size, having leaves less than 10 inches long and averaging scarcely 1/16 inch in width. Both samples were collected in Masset Inlet, April 10, 1941, and are now preserved in the botanical collection of the California Academy of Sciences.

Regarding brant, Stewart reported in March that relatively few of these birds winter in Masset Inlet, perhaps not more than 200 birds annually. This is apparently the northern limit for such numbers of brant in winter, although no information is available from the main coast. Stewart stated that the wintering birds are invariably extremely thin, averaging about 2 pounds in weight, and that he has never found any that exceeded 2½ pounds. Fat birds will sometimes weight 3½ pounds or more. This condition of the wintering birds indicates an inadequate food supply. Larger numbers of brant congregate in Masset Inlet in late spring, just before the northward migration. Stewart advised by letter, dated April 25, 1941, that normally there would be about a thousand birds in Masset Inlet on that date, but that this year "only a handful" were present. Local residents claim that the species was very plentiful many years ago, but that only a few now visit the area. These observations suggest some change in the status of eelgrass, the principal food of brant.

Vancouver Island.--J. A. Munro, Chief Federal Migratory Bird Officer for British Columbia, was at Nanaimo, Vancouver Island, in March 1941, at which time he inspected the local eelgrass beds and found them in good condition. He stated that D. Quaile had inspected a number of beds on the eastern shore of Vancouver Island, between Nanaimo and Victoria, and found them in normal condition. Further, that A. Teste, in connection with a study of herring spawning, had recently visited numerous beds on the west coast of Vancouver Island, between Barkley Sound and Winter Harbor and concluded that the crop in this area was heavier than normal.

R. E. Foster, Director of the Pacific Biological Station at Nanaimo, reported by letter, dated April 12, 1941, as follows: "We have quite recently had investigators in the field conducting a study of the spawning of herring, both along the west coast of Vancouver Island, in the Strait of Georgia, and in northern areas, and in no case have any of these observers noted any diminution in the supply of eelgrass. Particular attention was given to this matter, because eelgrass is a very important factor in the spawning of herring. With reference to conditions in past years, I know of no periods of scarcity, nor can I find any records of this. I am sure that if any definite diminution in the supply had occurred, we would have been advised, for it is related very closely to many of our fishery studies."

It is apparent from these reports that the eelgrass of Vancouver Island is still in a healthy condition. No reports have been received from the southern main coast of British Columbia. The Canadian authorities are fully aware of the danger of eelgrass depletion and will watch the plant closely for indications of disease.

Washington

Unfortunately, no reports have been received from the important lower Puget Sound area of Washington, where much eelgrass is known to occur, and where many brant winter (Moffitt 1934: 358-363), or from Gray's or Willapa harbors.

L. D. Phifer, of the University of Washington Oceanographic Laboratories, after a careful study during a period of minus tides in the Friday Harbor area, wrote on July 7, 1941, that "During a series of minus 2-foot-plus tides I have looked over the areas of Zostera above this tide level and estimate that the stands have decreased more than 50 percent net during the past 5 years in the localities in the San Juan Archipelago that have been under observation during this time. For this period I have field notes on the abundance of Zostera in various areas in the inter-tidal zone about the archipelago and on the general tendency for the areas to decrease in extent and vigor of growth. Many of the plants are in a condition similar to that described by Renn as the wasting disease. It is not surprising that the Zostera of this region should become infected with the disease, since it has been reported from Departure Bay, British Columbia, which lies just a few miles to the north."

Oregon

Netarts Bay.--Stanley G. Jewett, of the Fish and Wildlife Service, has been following the eelgrass situation along the Oregon coast since the fall of 1940. On September 27, 1940, Jewett photographed piles of eelgrass that had recently been washed upon the ocean beach just north of the entrance to Netarts Bay. These pictures showed the beach to be almost covered in places by piles of eelgrass a foot or more deep.

This is more than was found on the Atlantic coast in 1931, when the first evidence of the disease was the tremendous quantity of the plant washed up. The photographs suggest possibly a greater and certainly a more abrupt decline of eelgrass near Netarts Bay than has occurred even in some California bays.

Yaquina Bay.--Jewett inspected the eelgrass and collected samples from this bay on April 27, 1941. The plants did not show positive indications of the presence of Labyrinthula, but its occurrence was suspected. Jewett noted at the time that there was almost no mature growth present. In some places, however, there were satisfactory stands of plants with leaves from a few inches to a foot long. This condition has been found to be characteristic of conditions accompanying the disease on the Atlantic coast.

These reports indicate that the eelgrass depletion first reported from California, now occurs at least as far north as Departure Bay, British Columbia. The Netarts Bay finding suggests a sudden and great depletion which might be connected with a violent storm. Conditions in Tillamook Bay and at the mouth of the Columbia River should be further investigated.

California

Humboldt Bay.--This is California's most northern and most important brant resort. It normally has extensive eelgrass flats, which at times support large brant populations. More than 100,000 of these birds have been reported wintering in this bay during a single season (Moffitt 1935: 343, 1939: 337).

L. E. Lahr, State Game Warden at Eureka, for the past three winters, has been especially interested in brant, and he has contributed valuable information regarding eelgrass depletion. His report of February 10, 1941, stated that great reduction of the plant growth had occurred during the previous year. On March 7, 1941, Lahr investigated the eelgrass in North Humboldt Bay. Samples that he collected were found by Renn to be infected with Labyrinthula. Concerning the eelgrass, Lahr reported that it was then badly depleted, apparently because of the continuous feeding of large numbers of brant. In mid-October 1940 he stated that there were extensive growths of the plant in the bay, but in March 1941 these had been eaten off by brant to a depth of about 8 inches below mean low water "as if grazed by cattle." The beds seemed to be about as extensive as in 1938, but the grass composing them seemed to be thinner. Local fishermen told Lahr that in recent years the eelgrass had been decreasing, and he reported that he first noted eelgrass decline in 1938. In 1939 and 1940 there was no apparent shortage of the plant for the number of waterfowl then present, but the winter of 1940-41 brought numerous evidences of food deficiency.

Under date of April 28, 1941, Eldon Crosby, Secretary of the Eureka Fish and Game Club, wrote to the Fish and Wildlife Service to ascertain if possible what was thinning out the natural duck foods or grasses in Humboldt Bay. Eelgrass depletion may be the cause of this.

Bodega Bay.--Bert Laws, State Game Warden, reported on February 11, 1941, a very noticeable shortage of eelgrass. Several residents of the bay agreed that a considerable decline had occurred.

Tomales Bay.--Moffitt's observations for this area have already been cited. In the past year, several fisherman and hunters have remarked to him on the alarming scarcity of eelgrass. Nick Kojick, local commercial fisherman, has no eelgrass growing about his wharf where it was formerly abundant. He states that his fishermen have been unable to catch perch since most of the bay's eelgrass disappeared, and that in the past two winters herring runs have been small and spawning erratic.

Drakes Bay.--Oystermen of Tomales Bay, who also have oyster beds in Drakes Bay, have reported a large decrease of eelgrass in the latter locality comparable to that in Tomales Bay. R. J. Yates, State Game Warden, under date of July 15, wrote that the "eelgrass decline is so great that I have often wondered why the birds remain here * * *; they also feed on grass, however, far from the bay * * *."

Bolinas Bay.--Because of the eelgrass scarcity, Yates' comments are significant. He states, "At Bolinas Bay there were several hundred birds that ate up all of a rancher's pasture and kept me in trouble for 2 months in spite of shotgun shots fired to scare them away."

Morro Bay.--Hecker, State Game Warden, reported on February 10, 1941, that, in his opinion, eelgrass had declined in abundance, at least in the northern part of Morro Bay. He also noted in fall that the leaves of plants in the southern part of the bay had a "dead" appearance as if covered with a fine coating of silt. This description fits conditions observed by Moffitt in Tomales Bay in May, but Hecker's observations were made in autumn before winter rains brought down silt to the bay. On July 14 Hecker further reported that much of Moro Bay area that was in eelgrass 9 years ago is now filled with sand, and that the eelgrass has disappeared. He added that, "there is about half as much area covered with eelgrass today as compared with that of 9 years ago." He commented further that "you do not see the big drifts of eelgrass along the beaches at Baywood Park and other points around the bay that you did a few years ago * * *."

Point Mugu.--R. E. Bedwell, State Game Warden, Santa Barbara, made several inspections of the eelgrass growing near Point Mugu, Ventura County, in the winter of 1940-41. In February 1941 he concluded that there was no shortage of the plant and that there was enough food for two or three times the number of brant wintering there.

Anacapa Island.--G. Allan Hancock, University of Southern California, reported that on a visit to this island off the coast of Ventura County on March 16, 1941, eelgrass was found to be abundant.

San Diego and Mission Bays.---E. H. Glidden, State Game Warden, has cooperated with brant-census work in this locality for many years, and he is well acquainted with local conditions. Glidden surveyed eelgrass abundance in February, May, and June 1941, when he found an abundance of apparently healthy plants in Mission Bay. He thought that the growths west of the causeway bridges were larger than ever before.

After inspecting San Diego Bay in June 1941, Glidden wrote on June 30 that "strange as it may seem, we could not find the grass in the bay proper. The area where a short time ago the grass was plentiful, was covered by boat and on foot. The grass is completely gone from Cottonseed Point, as well as from the west side of the bay." It is significant that Labyrinthula has recently been found in eelgrass from this area. Only a few months earlier the eelgrass appeared to be normally healthy and abundant, although several causes were reducing its acreage. Silt deposits from seven dredges were covering beds of the plant, while reclamation by a salt company further reduced the available area at the south end of the bay.

Baja California (Lower California), Mexico

San Quintin Bay.---O. B. Cope (1940: 391) in reporting a census of black brant made on this bay on March 26, 1940, mentioned that floating fragments of eelgrass were fairly abundant.

Cedros Island.---G. Allen Hancock wrote that members of his expedition on February 27 1941, found eelgrass abundant and apparently healthy along the island's eastern coast.

Comments

These reports indicate that up to the spring of 1941, eelgrass was in normal and apparently healthy abundance at least from the Strait of Georgia northward, and from Santa Barbara County, Calif., southward along the Pacific coast. Definite indications of decline were reported for the area from Netarts Bay, Oreg., to Morro Bay, Calif. So far as is known, the first indications of depletion were observed in northern California bays in the winter of 1937-38. The rate of depletion was gradual and it did not become alarmingly extensive until the fall of 1940. In that season there occurred a sudden and an alarming loss at Netarts Bay, Oreg.

BRANT BEHAVIOR AND CENSUS RESULTS

In the course of counting brant, and while investigating eelgrass conditions, the observers noted numerous instances of marked departures from the normal feeding habits of black brant. Abnormal behavior, which seemed to indicate food shortage, and which was observed prior to the winter of 1940-41, has been recorded by Moffitt (1938: 345; 1939: 341; 1940: 386), and is mentioned earlier in this paper. The marked decrease of eelgrass in several California bays by the winter of 1940-41 apparently was responsible for the greatly increased number of reports of abnormal behavior by brant. All these reports emanated from areas of known eelgrass depletion.

While taking a brant census at Humboldt Bay on February 10, 1941, Game Warden Lahr observed a flock of about 400 of these birds in fairly deep water off Samoa, where a number of scaup ducks were diving for eelgrass. As the ducks rose to the surface with eelgrass in their bills, the brant would take every opportunity to rob them of it. Near the mouth of Salmon Creek, on the same date, Lahr found a flock of about a thousand brant in a field feeding on freshly sprouted grain. This was the largest number that he had ever seen feeding in a field. Since then Lahr reported, on March 7, 1941, that he had seen flocks of up to 2,000 brant feeding on new grass in fields some distance from the bay.

In November 1940, Moffitt observed a repetition of the unusual behavior of brant seen at Tomales Bay a year earlier (1940: 386), when the newly arrived winter visitants were slow to enter Tomales Bay to feed. In normal years the brant soon established regular daily flights from the ocean to the bay, the time depending upon the stage of the tide. In 1939 the birds were apparently reluctant to enter the bay. Early arrivals appeared by November 11, but regular flights were not observed until November 30. In 1940 the first wintering birds arrived on November 18, and rather irregular flights to the bay were observed on November 21 and 30, and on December 1. Even by December 14, when there were about 1,500 brant present, few entered the bay to feed, most of the birds going to the ocean off the mouth of the bay. Stomachs collected on these dates, and examined by the Fish and Wildlife Service, contained high percentages of rock grass, which is more abundant in the ocean than in the bay, thus confirming yield observations that the brant were feeding principally in the ocean.

In making the annual count on Tomales Bay on February 10, 1941, Moffitt and G. H. True, Jr., of the State Division of Fish and Game, saw small flocks of brant, apparently feeding on grass among the sand dunes near the bay, and others eating Salicornia near the water's edge. This plant, although succulent, is decidedly of abnormal use as a brant food.

The most radical departure from the normal habits of the brant at Tomales Bay, however, was observed by Moffitt and H. M. Worcester on May 7, 1941. Approximately 600 brant were present, a large number for that season. About 250 of these birds were seen apparently feeding on sea lettuce (Ulva) on the mud flats at the south end of the bay, where Moffitt had never before seen them. Formerly they were rarely found south of Marshall, 6 miles distant, probably because eelgrass had never occurred in quantity in that area. Cushing, however, reported brant feeding on algae at the south end of the bay in the winter of 1937-38 (Moffitt 1938: 345).

Most of the remaining brant seen on May 7 were found scattered along the bay's rocky western shore from White's Gulch opposite Hamlet to the ocean. Small flocks totaling about 250 birds were found on or near the beaches where there was no eelgrass, but where algae could be found. Of these, about 40 birds were seen feeding on sandy and rocky bottom off Avalis Beach, just outside the bay, where close inspection showed the only food present to be algae, mainly red alga (Gracilaria confervoides), with green alga (Ulva lactuca) epiphytic upon it. Neither is of much nutritive value. A short distance beyond these brant, a smaller group was feeding on rocks exposed by the low tide. When the first birds were disturbed, they joined the second lot, where the aggregation was for some time seen feeding, climbing over the rocks and swimming in the small crevasses between them in the manner of shorebirds. It was quite evident that the brant were feeding on the leaves of the rock grass abundant there. When these birds were disturbed, some of them flew back to Avalis Beach.

At this time, when the tide was favorable for brant to feed in the customary place on the eelgrass flats off Hamlet, not more than 100 of the 400 or more birds present were found there. As previously mentioned, there seemed to be enough silt-encrusted eelgrass readily available for more than the number of birds present, yet most of them seemed to prefer such usually less desirable foods as rock grass and algae. This strongly suggested that the brant did not care to eat the silty or diseased eelgrass.

Ben Glading, of the California Division of Fish and Game, stationed at Pacific Grove, Calif., submitted a photograph, taken on April 3, 1941, of 56 black brant feeding on the Pebble Beach Golf Course, 17 Mile Drive, in Monterey County. Glading reported that the birds could not be frightened away and that they fed for a number of days upon grass on the golf course, where their presence was disconcerting to the golfers. This behavior certainly reflects a shortage of their normal food.

In reporting upon the brant census, which he took on Morro Bay on February 10, 1941, Game Warden Hecker stated that about 4,000 of the birds counted were feeding along sloughs on the east and south sides of the bay upon Salicornia, locally termed "salt" or "baloney" grass. This is not their accustomed food, and the birds raised their heads high as they fed, appearing to have difficulty in swallowing.

Stomach contents of a brant collected on December 31, 1932, in the ocean just outside the mouth of Tomales Bay may be regarded as normal for the season. The stomach was full, including 27.7 cc. of food and 8.5 cc. of gravel. Pieces of eelgrass, some ½ inch wide and 16 inches long, comprised 63 percent of the food volume. Adhering for the most part to the Zostera, fragments of approximately 6,000 small fish eggs, probably those of herring, amounted to 26 percent. Leafy fragments of Phyllospadix, one piece 18 inches long, made up 10 percent of the food content, while a trace of sea lettuce was present. An amphipod and an isopod comprised 1 percent. Contents of 4 other stomachs collected by J. E. Cushing in Drakes Estero, Marin County, Calif., on November 29 and 30, 1936, also evidenced normal food habits in the area before the eelgrass depletion. Two of these, which were, respectively, full and 2/3 full, contained only plant fiber of Z. marina. The average content of the 4 stomachs was: Eelgrass, 95.5 percent; sea lettuce, 4 percent; and undetermined plant fiber, 0.5 percent.

The gorged gullet and stomach of a brant collected near eelgrass beds on the eastern side of Tomales Bay north of Marshall at 5:30 p.m. on April 22, 1939, was remarkable in that it contained no Zostera. The contents amounted to 60 cc. and consisted entirely of marine algae. Sea lettuce comprised 50 percent of the bulk, green algae (Enteromorpha), 20 percent, and undetermined algae, 30 percent. Eelgrass was available, but it had not been eaten. The bird was fat, weighing 3½ pounds.

Results of examination of stomachs of 14 brant shot in 1940 at Tomales Bay (p. 16) are interesting in that they give evidence of a shortage of eelgrass by the relative increase in the unusual food content. Of these stomachs 7 were taken on November 21, 5 on November 30, and 2 on December 1, 1940. The average content for the whole lot was as follows: Zostera, 47 percent; Phyllospadix, 51 percent; and undetermined plant fiber and hydroids, 1 percent each. Three of the stomachs collected on November 21 held only rock grass, while this plant predominated in 3 others. All the brant were shot early in the morning as they entered the bay to feed, so their stomachs were fairly empty. The food volume ranged from 0.2 cc., or practically empty, to 10 cc. in two instances, and averaged a little more than 5 cc. Most of the birds were quite fat, and all were in good condition, but it must be remembered that they had only recently arrived in the vicinity. As the gunning season closed in mid-December, no birds were collected later.

Results of counts of black brant in California bays in recent years show decreases in the numbers of wintering birds in most localities where eelgrass depletion has occurred, while in the same period numbers of brant wintering in Mission and San Diego bays have increased sharply. It is significant that no eelgrass depletion was reported in these two bays before July 1941. Table 1 below indicates these trends. Results are given for the last 5 seasons for all bays from which counts have been obtained during the past 10 or 11 years as well as averages for the whole period. Drakes Bay has been omitted because, unfortunately, no censuses were made there in 1931 or 1941. The censuses were taken annually, on or about February 10, in all localities.

TABLE 1.--Annual census of brant in California bays, 1937-41

Bay	1937	1938	1939	1940	1941	Average[1/]
Humboldt	22,500	45,000	29,000	56,375	50,000	*40,915
Bodega	1,500	1,475	1,100	1,050	555	*1,520
Tomales	1,556	3,085	9,241	4,916	1,540	5,915
Morro	5,331	5,738	11,140	7,263	6,302	*5,964
Mission	450	325	570	1,395	2,500	510
San Diego	350	397	462	13	442	157
Totals	31,687	56,020	51,513	71,012	61,339	*54,688

[1/] Averages are for 11 years, 1931-41, unless preceded by a star (*), when they are for 10 years.

As in the case of all California brant censuses, the result in Humboldt, the most important bay, largely controls the totals. The counts in this bay from 1939 to 1941 do not reflect the eelgrass depletion which is known to have occurred in this period. Large and unexplainable fluctuations in numbers of wintering brant from year to year have been the rule at Humboldt Bay throughout the census work. The effect of eelgrass shortage is thought to be the cause for the progressive reduction in numbers of wintering brant in Bodega, Tomales, and Morro bays since 1939. During the same period, increases for Mission Bay, especially, are plainly evident.

The totals for the first 2 seasons are, by reason of the large Humboldt Bay counts, greater than the averages for 10 years despite the eelgrass decline. This is perhaps the result of a gradual increase in the numbers of black brant through the census years, reaching a peak in 1940, with the exception of the year 1935, when the greatest count of all, 125,153 birds for California, was obtained. As Moffitt (1934: 364; 1935: 350; 1937: 295) has pointed out, it is difficult or impossible to determine Pacific coast brant population trends from the California censuses alone. Most brant are known to winter in Baja California, where they apparently arrive as winter

visitants earlier in fall than they do on the California coast (Moffitt 1931: 397; 1932: 304; 1934: 357; 1935: 344; 1936: 299; 1938: 344; 1939: 339). They appear in California bays from late September on, the early flocks remaining but a day or two before continuing southward. The birds do not stop in California bays until about mid-November, when some individuals, apparently southbound migrants, do so to winter. From January to March the usually small wintering population is greatly augmented by flights from the South. The greatest concentrations occur in California bays in mid-March, just before the main northward migration. Because of this and the apparent irregularity of the northward midwinter flight to California in different seasons, it is impossible to estimate the Pacific coast brant population without simultaneous counts in California and Baja California.

That brant tend to winter in the same area, year after year, was evidenced by Moffitt's report of a peculiarly marked, albinistic bird that was recorded in Morro Bay, Calif., each winter for 23 years (Moffitt 1937: 294). The observation was made by A. J. Silva, a long-time resident and brant hunter of the area, who shot the bird in November 1936. The fluctuations in the census results from year to year, however, show that all brant are not so regular in returning to the same wintering grounds. The tendency to return is important in its relation to eelgrass depletion, for some brant may become so accustomed to wintering in a certain bay that they would not go elsewhere even under the stress of severe food shortage.

It is especially important at this time to investigate eelgrass conditions and brant food supplies in Baja California. The scant information at hand indicates that the eelgrass depletion probably has not yet reached Baja California. It is possible that the condition in California and the west coast generally will become more severe, in which case the brant will be in a precarious state. It is doubtful, however, that the situation will become as serious as that which developed in the East from 1931 to 1938, because of the more gradual and less virulent attack of the eelgrass disease on the west coast, and because rock grass, which is fairly common in favorable rocky habitats, is known to be an acceptable substitute for eelgrass in the diet of the brant.

SUMMARY

1. Eelgrass, a perennial pondweed occurring on both north coasts of the Atlantic and Pacific Oceans, is of direct and indirect benefit to man in that it favors many kinds of fishes, shellfishes, and crustaceans and is an important food for wildfowl, especially sea brant.

2. More than 90 percent of the plant growth abruptly died out on the coasts of the north Atlantic Ocean from 1931 to 1933, and its recovery was slow and sporadic until 1939. Since that time recovery has been encouraging, the best improvement being in areas of reduced salinity.

3. A complete and satisfactory explanation of the cause of this destruction has not been offered, although it appears that a low form of fungus, a mycetozoan of the genus Labyrinthula, is to some degree responsible. A change in the water environment has apparently permitted this organism to become destructive.

4. The depletion of eelgrass on the North American coast of the Atlantic had a very serious effect upon sea brant, causing a reduction of perhaps 80 percent in the entire population wintering in the region.

5. Since 1938 a gradual decrease in the abundance of eelgrass has been in evidence on the Pacific coast of the United States from Morro Bay in southern California to Departure Bay, British Columbia, and the diminution extends in different areas from a mere trace to fully 50 percent.

6. The mycetozoan Labyrinthula has been found in a number of samples submitted for laboratory study. Furthermore, the appearance of diseased plants from the west coast resembles that of diseased specimens from the east coast of the United States.

7. The food habits and general behavior of sea brant have shown marked changes in areas where eelgrass is scarce.

8. It is possible that the eelgrass situation along the west coast will become more critical, in which case the brant will be in a precarious state. It is doubtful, however, that the situation will become as serious as that which developed in the East from 1931 to 1938, because of the more gradual and less virulent attack of the eelgrass disease on the west coast, and because rock grass, which is fairly common in favorable rocky habitats, is known to be an acceptable substitute for eelgrass in the diet of the brant.

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